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REPORT

ON

KEECHELUS LAKE

KITTITAS COUNTY

WASHINGTON

EPA REGION X

WORKING PAPER NO. 869

WITH THE COOPERATION OF THE

WASHINGTON DEPARTMENT OF ECOLOGY

AND THE

WASHINGTON NATIONAL GUARD

JULY, 1977

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16 ABSTRACT

Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivided according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

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REPORT ON KEECHELUS LAKE

KITTITAS COUNTY, WASHINGTON

EPA REGION X

by

National Eutrophication Survey

Water and Land Quality Branch
Monitoring Operations Division
Environmental Monitoring & Support Laboratory
Las Vegas, Nevada

and

Special Studies Branch
Corvallis Environmental Research Laboratory
Corvallis, Oregon

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U.S. ENVIRONMENTAL PROTECTION AGENCY

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to freshwater lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point source discharge reduction and nonpoint source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's freshwater lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by the U.S. Environmental Protection Agency and to augment plans implementation by the states.

ACKNOWLEDGMENTS

The staff of the National Eutrophication Survey (Office of Research and Development, U.S. Environmental Protection Agency) expresses sincere appreciation to the Washington Department of Ecology for professional involvement, to the Washington National Guard for conducting the tributary sampling phase of the Survey, and to those Washington wastewater treatment plant operators who provided effluent sample and flow data.

Ms. Barbara Blau, Lake Restoration Program, and the staff of the Washington Department of Ecology, Lake Restoration Program, provided invaluable lake documentation and counsel during the Survey, reviewed the preliminary reports and provided critiques most useful in the preparation of this Working Paper Series.

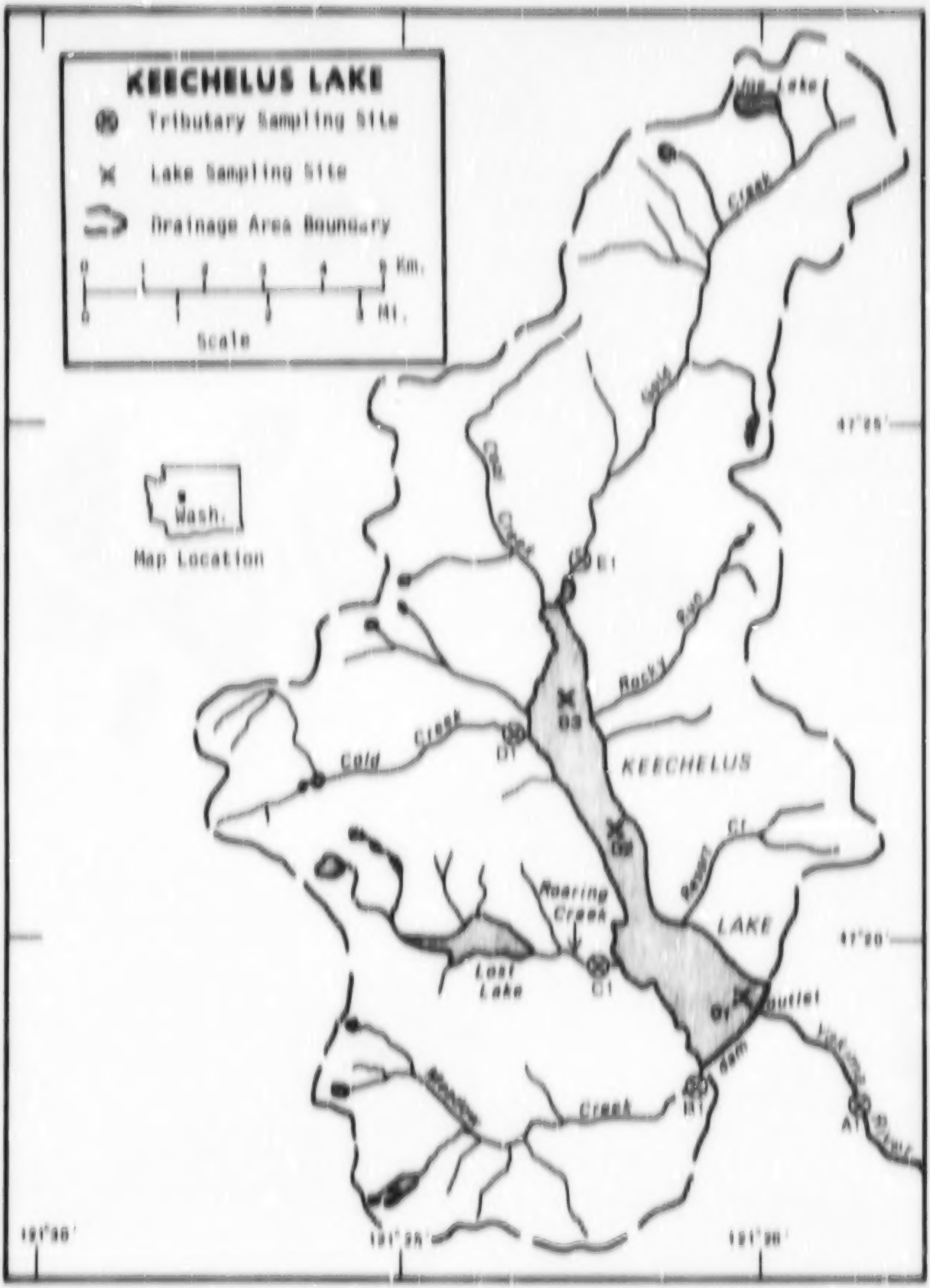
Major General Howard S. McGee, Adjutant General of Washington, and Project Officer Colonel Clinton C. Johnson, who directed the volunteer efforts of the Washington National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

NATIONAL EUTROPH ATION SURVEY

STUDY LAKES

STATE OF WASHINGTON

LAKE NAME	COUNTY
American Lake	Pierce
Banks Lake	Grant, Douglas
Chelan Lake	Chelan
Diamond Lake	Pend Oreille
Green Lake	King
Keechelus Lake	Kittitas
Mayfield Lake	Lewis
Medical Lake	Spokane
Moses Lake	Grant
Ozette Lake	Clallam
Sammamish Lake	King
Lake Whatcom	Whatcom
Lower Granite Reservoir	Garfield, Whatcom


KEECHELUS LAKE
Tributary Sampling Site
Lake Sampling Site
Drainage Area Boundary
Km.
Mi.
Scale
Wash.
Map Location
Cold Creek
Rocky Run
KEECHELUS
LAKE
Roaring Creek
Lost Lake
Outlet
Dam
Creek
47°25'
47°20'
121°30'
121°25'
121°20'

REPORT ON KEECHELUS LAKE, WASHINGTON

STORET NO. 5306

I. CONCLUSIONS

A. Trophic Condition:*

Survey data indicate that Keechelus Lake is oligotraphic. Chlorophyll a values in the lake ranged from 0.5 µg/l in July to 2.1 µg/l in October, with a mean of 1.4 µg/l. Potential for primary production as measured by algal assay control yields was low on all three sampling occasions. Lake water transparency was excellent. Of the 13 Washington lakes sampled in 1975, 11 had higher median total phosphorus and inorganic nitrogen values, and all had higher median orthophosphorus levels than Keechelus Lake.

Survey limnologists did not report any problem algal blooms or macrophytes during their visits to the lake.

*See Appendix F.

B. Rate-Limiting Nutrient:

The algal assay results indicate that Keechelus Lake was limited by available phosphorus on all three sampling dates (07/21/75, 09/12/75, 10/28/75). Lake data suggest nitrogen limitation during the July sampling and phosphorus limitation during September and October.

C. Nutrient Controllability:

1. Point sources -

There were no known municipal or industrial point sources impacting Keechelus Lake during the sampling year. The present phosphorus loading of 0.44 g $P/m^2/yr$ is less than that proposed by Vollenweider (1975) as an "oligotrophic" level. Unless this loading rate is substantially increased, the excellent trophic condition of Keechelus Lake should be maintained.

2. Nonpoint sources -

Meadow Creek contributed 17.4% of the total phosphorus loading to Keechelus Lake. Gold Creek contributed 22.6% and the minor tributaries and immediate drainage contributed 56.0%.

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS:

Lake and drainage basin characteristics are itemized below. Lake morphometry data were provided by Walcott (1965). Tributary flow data were provided by the Washington District Office of the U.S. Geological Survey (USGS). Outlet drainage area includes the lake surface area. Mean hydraulic retention time was obtained by dividing the lake volume by mean flow of the outlet. Precipitation values are estimated by methods as outlined in National Eutrophication Survey (NES) Working Paper No. 175. A table of metric/English conversions is included as Appendix A.

A. Lake Morphometry:

1. Surface area: 10.36 km^2.
2. Mean depth: 18.7 meters.
3. Maximum depth: 27.4 meters.
4. Volume: 193,650 x 10^6 m^3.
5. Mean hydraulic retention time: 220 days.

B. Tributary and Outlet:
(See Appendix B for flow data)

1. Tributaries -

Name	Drainage area (km^2)	Mean flow (m^3/sec)
B-1 Meadow Creek	20.4	1.47
C-1 Gold Creek	36.3	2.61
Minor tributaries and immediate drainage -	74.6	6.12
Totals	131.3	10.20
2. Outlet - A-1 Yakima River	141.7	10.18

C. Precipitation:

1. Year of sampling: 210.2 cm.
2. Mean annual: 167.2 cm.

III. LAKE WATER QUALITY SUMMARY

Keechelus Lake was sampled three times during the open-water season of 1975 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from three stations on the lake and from a number of depths at each station (see map, page v). During each visit, depth-integrated samples were collected from each station for chlorophyll *a* analysis and phytoplankton identification and enumeration, and 18.9-liter depth-integrated samples were composited for algal assays. Maximum depths sampled were 29.0 meters at Station 01, 58.2 meters at Station 02, and 4.3 meters at Station 03. For a more detailed explanation of NES methods, see NES Working Paper No. 175.

The results obtained are presented in full in Appendix C and are summarized in III-A for waters at the surface and at the maximum depth for each site. Results of the phytoplankton counts and chlorophyll *a* determinations are included in III-B. Results of the limiting nutrient study are presented in III-C.

B. Biological Characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Algal Units per ml
07/21/75	1. Cyclotella	466
	2. Chroomonas	89
	3. Melosira	80
	4. Cryptomonas	22
	Other genera	11
	Total	666
09/12/75	1. Chlorophytan Cell	195
	2. Dinobryon	195
	3. Melosira	130
	4. Cryptomonas	22
	Other genera	11
	Total	542
10/28/75	1. Chroomonas	24
	2. Dinobryon	24
	Other genera	11
	Total	48

2. Chlorophyll a -

Sampling Date	Station Number	Chlorophyll a (µg/l)
07/21/75	01	0.5
	02	1.4
	03	1.0
09/12/75	01	1.2
	02	1.5
	03	1.4
10/28/75	01	1.2
	02	1.6
	03	2.1

C. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

a. 07/21/75

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum Yield (mg/l-dry wt.)
Control	<0.005	0.083	0.3
0.05 P	<0.055	0.083	3.5
0.05 P + 1.0 N	<0.055	1.083	23.4
1.00 N	<0.005	1.083	0.4

b. 09/12/75

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum Yield (mg/l-dry wt.)
Control	0.005	0.040	0.3
0.05 P	0.055	0.040	3.5
0.05 P + 1.0 N	0.055	1.040	21.3
1.00 N	0.005	1.040	0.3

c. 10/28/75

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum Yield (mg/l-dry wt.)
Control	0.005	0.035	0.2
0.05 P	0.055	0.035	0.9
0.05 P + 1.0 N	0.055	1.035	25.9
1.00 N	0.005	1.035	0.2

2. Discussion -

The control yields of the assay alga, Selenastrum capricornutum, indicate that the potential for primary productivity in Keechelus Lake was moderately low during the three sample collection times (07/21/75, 09/12/75, 10/28/75). In each assay a significant increase in yield over that of the control occurred when phosphorus was added alone and in combination with nitrogen, indicating phosphorus limitation. The addition of nitrogen alone did not stimulate growth significantly beyond the control yields.

The mean inorganic nitrogen to orthophosphorus ratios in the lake samples were approximately 9/1, 17/1, and 18/1 on the July, September, and October sampling dates, respectively, suggesting nitrogen limitation during the July sampling period and phosphorus limitation during September and October.

IV. NUTRIENT LOADINGS
(See Appendix D for data)

For the determination of nutrient loadings, the Washington National Guard collected near-surface grab samples from each of the tributary sites indicated on the map (page v). Sampling was begun in September 1974, and was completed in August 1975.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Washington District Office of the USGS for the tributary sites nearest the lake.

In this report, nutrient loads for sampled tributaries were determined by using a modification of a USGS computer program for calculating stream loadings. Nutrient loads indicated for tributaries are those measured minus known point source loads, if any.

Nutrient loadings for unsampled minor tributaries and immediate drainage" ("ZZ" of USGS) were estimated by using the mean annual nutrient loads, in $kg/km^2/yr$, in Meadow Creek and Gold Creek at Stations B-1 and E-1 and multiplying the means by the ZZ area in km^2.

A. Waste Sources:

1. Known municipal - None

2. Known industrial - None

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	kg P/yr	% of total
a. Tributaries (nonpoint load) -		
B-1 Meadow Creek	785	17.4
E-1 Gold Creek	1,025	22.6
b. Minor tributaries and immediate drainage (nonpoint load) -	2,535	56.0
c. Known municipal STP's - None		
d. Septic tanks* - None		
e. Known industrial - None		
f. Direct precipitation**-	180	4.0
Totals	4,525	100.0
2. Outputs - A-1 Yakima River	1,685	
3. Net annual P accumulation -	2,840	

*Dion, N.P. et al., 1975.
**Estimated (See NES Working Paper No. 175).

C. Annual total Nitrogen Loading - Average Year:

1. Inputs -

Source	kg N/yr	% of total
a. Tributaries (nonpoint load) -		
B-1 Meadow Creek	8,240	8.6
C-1 Cold Creek	30,305	31.8
b. Minor tributaries and immediate drainage (nonpoint load) -	46,250	48.2
c. Known municipal STP's - None		
d. Septic tanks* - None		
e. Known industrial - None		
f. Direct precipitation** -	11,185	11.6
Total	95,980	100.0
2. Outputs - A-1 Yakima River	40,835	
3. Net annual N accumulation -	55,145	

*Dion, N.P. et al., 1976.
**Estimated (See NES Working Paper No. 175).

D. Mean Annual Nonpoint Nutrient Export by Subdrainage Area:

Tributary	kg P/km²/yr	kg N/km²/yr
Meadow Creek	19	404
Gold Creek	28	830

E. Mean Nutrient Concentrations in Ungaged Streams:

Tributary	Mean Total P (mg/l)	Mean Total N (mg/l)
C-1 Roaring Creek	<0.007	<0.240
D-1 Cold Creek	<0.007	<0.265
I-F Cedar Creek*	<0.006	0.220
I-G S. Fork Cedar River*	<0.008	<0.227
I-H Rix River*	<0.010	0.323
I-J Boulder Creek*	<0.011	0.319
I-K Smay Creek*	0.010	0.328
I-L Friday Creek*	0.022	<0.225
I-M Greer River*	<0.010	<0.116

*Special interest streams outside the watershed of Keechelus Lake.

F. Yearly Loadings:

In the following table, the existing phosphorus annual loading is compared to the relationship proposed by Vollenweider (1975). Essentially, his "eutrophic" loading is that at which the receiving waters would become eutrophic or remain eutrophic; his "oligotrophic" loading is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A "mesotrophic" loading would be considered one between "eutrophic" and "oligotrophic".

Note that Vollenweider's model may not apply to lakes with short hydraulic retention times or in which light penetration is severely restricted by high concentrations of suspended solids in the surface waters.

	Total Yearly Phosphorus Loading ($g/m^2/yr$)
Estimated loading for Keechelus Lake	0.44
Vollenweider's "eutrophic" loading	1.08
Vollenweider's "oligotrophic" loading	0.54

V. LITERATURE REVIEWED

Dion, N.P., G.G. Bortleson, J.B. McConnell and L.M. Nelson. 1976. Reconnaissance Data on Lakes in Washington, Volume 5, (Chelan, Ferry, Kittitas, Klickitat, Okanogan, and Yakima Counties). Washington State Department of Ecology, Water Supply Bulletin 43, Volume 5.

U.S. Environmental Protection Agency. 1975. National Eutrophication Survey Methods 1973-1976. Working Paper No. 175. National Environmental Research Center, Las Vegas, Nevada, and Pacific Northwest Environmental Research Laboratory, Corvallis, Oregon.

Vollenweider, R.A. 1975. Input-Output Models With Special Reference to the Phosphorus Loading Concept in Limnology. Schweiz. Z. Hydrol. 37:53-84.

Wolcott, E.E. 1965. Lakes of Washington, Volume II. Washington Division of Water Resources, Water Supply Bulletin, 14 and 15.

VI. APPENDICES

APPENDIX A
CONVERSION FACTORS

CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x 8.107×10^{-4} = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

APPENDIX B

TRIBUTARY FLOW DATA

APPENDIX C

PHYSICAL AND CHEMICAL DATA

APPENDIX D

TRIBUTARY AND WASTEWATER TREATMENT PLANT DATA

[redacted]

[illegible]

[redacted]

APPENDIX E

PARAMETRIC RANKINGS OF LAKES
SAMPLED BY NES IN 1975

STATE OF WASHINGTON

Mean or median values for six of the key parameters evaluated in establishing the trophic conditions of Washington lakes sampled are presented to allow direct comparison of the ranking, by parameter, of each lake relative to the others. Median total phosphorus, median inorganic nitrogen and median dissolved orthophosphorus levels are expressed in mg/l. Chlorophyll a values are expressed in ug/l. To maintain consistent rank order with the preceding parameters, the mean Secchi disc depth, in inches, is subtracted from 600. Similarly, minimum dissolved oxygen values are subtracted from 15 to create table entries.

LAKE DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	[illegible] TOTAL P	[illegible] INORG N	[illegible] MEAN SEC	[illegible] CHLPHA	[illegible] MIN DO	[illegible] DEPTH SMPLD P
5301	AMERICAN LAKE	0.027	0.195	343,888	4,822	15,000	0.007
5302	BANKS LAKE	0.021	0.049	334,533	7,373	10,439	0.007
5303	CHELAN LAKE	0.005	0.070	111,900	0.005	6,443	0.003
5304	DIAMOND LAKE	0.014	0.069	193,447	14,537	14,700	0.010
5305	DEEP LAKE	0.027	0.050	435,000	2,003	10,400	0.004
5306	KEECHELUS LAKE	0.007	0.040	280,250	1,408	0,200	0.002
5307	MAYFIELD LAKE	0.014	0.199	402,000	4,250	10,600	0.007
5308	MEDICAL LAKE	0.375	0.225	491,734	38,425	75,000	0.147
5309	MOSES LAKE	0.115	0.150	443,600	29,000	24,600	0.730
5310	OLETTE LAKE	0.018	0.110	493,333	1,235	7,230	0.000
5311	SAMMAMISH LAKE	0.015	0.251	376,000	7,700	14,400	0.004
5312	WHATCOM LAKE	0.009	0.307	299,000	3,427	10,400	0.005
5313	LOWER YAKIMA RESERVOIR	0.033	0.150	475,500	4,675	7,200	0.029

| | | |